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RESEARCH ARTICLE

Evaluation of Variation Orders on Road Construction Projects in Rural Nepal

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Abstract

Variation orders (VOs) contribute to time and cost overruns in Nepalese road projects and often trigger disputes. This mixed-methods study examined the causes of VOs on rural roads in Karnali Province using a targeted literature review, field observations, document review, case studies of 11 client–contractor–consultant projects (located for geographic spread, contractor size, and presence/absence of consultant oversight), and a closed-ended census survey of industry professionals across the three stakeholder groups. Quantitative analysis used the Relative Importance Index (RII) and descriptive statistics to compare stakeholder perceptions; qualitative evidence from site observations and documents triangulated the results. The findings identified variations in scope of work (additions, omissions, and alterations in employer requirements) as the primary cause (RII clients = 812; RII consultants = 780; RII contractors = 791). Secondary causes vary by stakeholder: clients and contractors rank "change in design and drawings by consultant" highly (RII 0.800), while consultants and contractors emphasize "errors and omissions in design" (RII consultants = 933; RII contractors = 864). Other contributors include inadequate site investigation, adverse site conditions, government intervention, and client-initiated changes. Stakeholders differ on causes but largely agree on effects

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and mitigation strategies. The study's originality is its stakeholdercomparative mixed-methods focus on Karnali rural roads, producing empirically grounded, actionable mitigation measures. Improving scope definition, completing designs, and strengthening early site investigation can substantially reduce VOs. The paper recommends coordinated national research led by academic and professional bodies, in partnership with government and industry, to develop standardized guidance and capacity-building.

Keywords

Variation Order; Cost Variation; Time Variation; Causes; Impacts

Introduction

As Nepal transitioned to a federal system of government, the central government shifted political authority and development emphasis to the provinces, which accelerated road construction nationwide. Federalism empowered provinces to access local infrastructure requirements, and development has made uneven strides. Karnali Province, Nepal's remotest and topographically difficult region, has fallen behind in rising investment. Its steep topography, loose soils, and weathered land are softened by the technical challenges that even the best plans cannot resolve easily. Limited institutional capacity and a lack of experienced project managers, engineers, and surveyors exacerbate the challenge faced by governments in planning, monitoring, and adjusting projects in low- and middle-income countries. Compounding it all is the prevalence of variation orders (VOs), formal changes to the contracted scope of work that are almost ubiquitous and regrettably widely considered as "normal". Empirical research reveals continual unrestrained variations evidenced by cost overruns, project delay, and contractual problems (Borowy, 2013; Francis et al., 2022; Pillai et al., 2002). Although VOs are extensively studied throughout the world (Abd El-Karim et al., 2017), technical uncertainty, weak governance, and sociopolitical influence in remote, risk-prone zones like Karnali are still inadequately researched. This disparity is significant: strategies that work in lowland or urban emergencies where access to sites is stable, resources are relatively settled, and data sources are reliable fall short in settings experiencing the ever-changing hazards and the political realities of facility operations.

The Ministry of Physical Infrastructure and Urban Development (MoPIUD) is responsible for road development in Karnali. Institutional problems and environmental turbulence continue to plague MoPIUD projects. Poor feasibility studies, underestimating geotechnical risks, and inadequate supervision of site investigations lead to technical design problems that only become apparent during widespread implementation, often requiring costly mid-design revisions.

Political intervention may override technical counsel, altering alignments or scope enlargement without corresponding resource increases. Environmental hazards such as landslides, flash floods, and seasonal erosion threaten project progress. In such conditions, VOs help keep projects viable rather than serving only as corrective measures (H. K. Doloi, 2011; H. Doloi et al., 2012a; Sewell et al., 2019a). It is too great a risk; two districts are fully cut off from Nepal's road network, underscoring the price of development in delay and inefficiency (Weingast, 2009).

Studies worldwide have identified various reasons for VOs, such as design errors, stakeholder-requested changes, or procurement problems (Aziz and Abdel-Hakam, 2016; Ghorasainee, 2019). Nonetheless, most of these studies examine settings with stable governance, similar site conditions, and stronger contract enforcement. Very few examine the interactions of geologic risk and governance weakness together. Recent literature highlights this gap. Heyns and Banick (2024) noted the lack of VO-based development research in South Asia to prevent the inappropriate transfer of irrelevant models. Mukherjee et al., (2023) advocated for a collaborative, technology-supported solution (e.g., remote sensing, digital progress monitoring, and online communication) that will develop resilience. With the road weaving over hills and down river valleys in Karnali, these tools could predict landslides, survey bank erosion, and give engineers a heads-up to respond.

In Nepal's mountain provinces, locally limited empirical data create constraints on decision-making at policy and project levels. Without local data, contracts, contingency plans, and design standards may rely on assumptions that fail in practice. This study explored this gap by systematically investigating wants for VO causes and impacts and VO prevention in all 10 districts of Karnali Province. This research employed a mixed-methods approach that included a literature review to position the problem in the context of international and regional theory, case studies of 11 MoPIUD projects to reflect local realities, and a survey to garner responses from engineers, contractors, and administrators.

Karnali geophysical instability is a long-term cause of VOs. On the Karnali Highway and other trunk roads, rainstorms during the monsoons cause slope collapses and riverbank erosion, and flash floods sweep away partly built works. Such events necessitate rapid redesigning, reshaping road sections, enhancing drainage, or strengthening structures, all of which create VOs (Corominas et al., 2014). Nepal's legal framework delineates sequential approval and conflict resolution processes as shown in Figure 1, but in practice, safety and continuity often require spontaneous field adjustments before formal authorization.

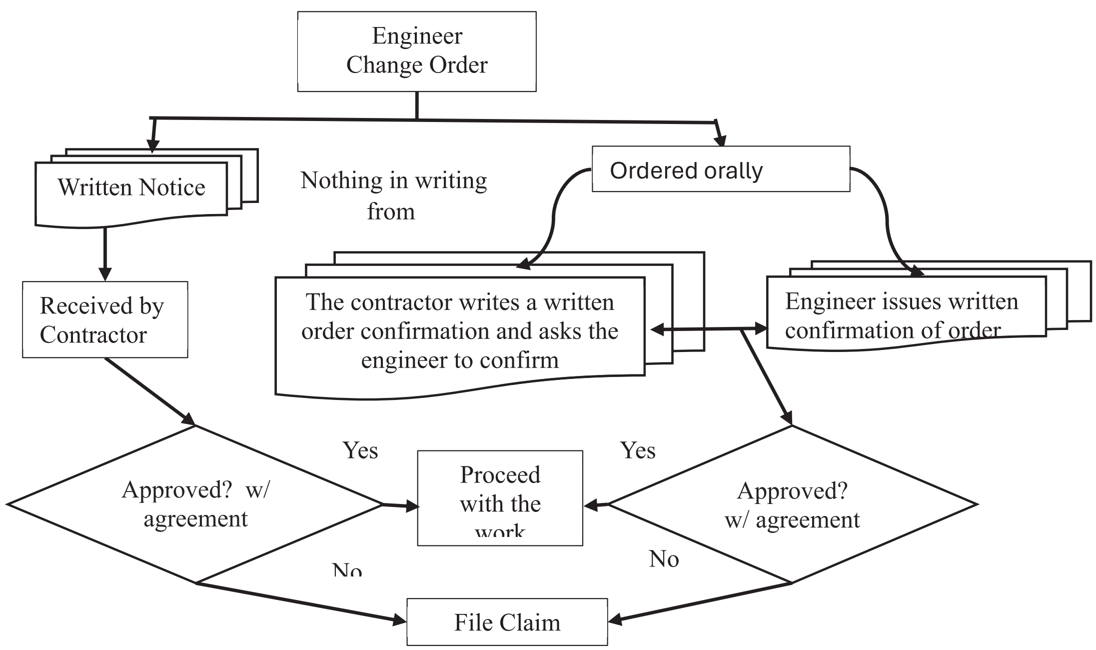


Figure 1. Conceptual flowchart of variation orders in construction project

As mentioned in Figure 2, repeated natural disasters impact building times, severing access, inundating sites, and undermining foundations. With such a climate, VO management must be forward-looking and strategic rather than reactionary (Sidle and Ziegler, 2025). This involves incorporating flexibility into contracts, setting aside contingency budgets, and allowing site teams to implement swift, technically sound adaptations. Studying VO dynamics in one of Nepal's most geophysical and institutionally challenging regions shows that VO management systems cannot be applied universally without adapting to the local context. The results are of dual significance: theoretically, they contribute to the understanding of how environmental ambiguity and limitations in governance structure interact to initiate project change; practically, they can be used to guide contract design, early warning systems, and institutional capacity-building for infrastructure delivery in similarly challenging environments around the world. The goal is not to eliminate change, an impossibility in Karnali, but to channel it as a controlled, open, and constructive process supporting public infrastructure successes.

Figure 2. (a) Karnali Highway obstructed due to landslides. (b) Karnali Highway blockade due to floods and landslides. (c) Karnali Highway blockade due to scoring. (d) Karnali Highway at the Rocky Mountains

Theoretical/literature review

On construction projects, the variation orders come more often with well-established consequences of delays in the scheduling, budget overruns, cash flow challenges, and defects in the quality (Koirala and Shahi, 2024a; Sobaih et al., 2024). Variation management has always played a major role in project success due to scarce resources, difficult logistics, and challenging site conditions on rural highway projects such as those in Karnali Province. In situations like building rural highways in Karnali Province, a rural area with scarce resources, logistical challenges, and difficult site conditions, effective VO management has a significant impact on the success of the project.

From the literature, this research identifies five essential factors that impact variation orders, namely (1) client and consultant behavior, (2) contractor capacity, (3) environmental and external factors, (4) project management processes, and (5) systemic and regulatory environments. All five factors work together to determine the occurrence and effect of variation orders on a project. In unison, they determine to what degree variation orders affect a project.

1. CLIENT AND CONSULTANT ISSUES

Scope changes requested by the clients, design changes, or additional work requested, without conducting a rigorous technical evaluation in most cases, are the most frequent contributors to VOs (D'Astous et al., 2004; Maqbool and Rashid, 2017). Consultants can also produce incomplete or conflicting design documents or sometimes do not carry out investigations on-site. Failures in drawing coordination occur. These problems interfere with the planned work sequence and require variations (Oloo et al., 2014; Dosumu and Aigbavboa, 2017).

2. CONTRACTOR CAPABILITY AND MANAGEMENT

The competence of contractors directly affects VO occurrence. Inadequate site supervision, defects in construction, and mismanagement of resources are usually accompanied by remedial work and contract variations (H. Doloi et al., 2012b; Koirala and Shahi, 2024b). Inefficient subcontractors and a low-skilled workforce can compound these deficiencies.

3. EXTERNAL FACTORS AND ENVIRONMENTAL CONDITIONS

Several external factors can affect construction contracts beyond the parties' control. Unfavorable weather conditions, unanticipated ground conditions, political interference, budgetary uncertainty, material shortages, and price fluctuations can lead to spontaneous variation orders (Alshihri et al., 2022; Wang et al., 2024). All these issues create uncertainty, which increases the chance of variation orders.

4. SHORTCOMINGS IN PROJECT MANAGEMENT AND PLANNING

When planning for the project is poor, when there is weak communication between stakeholders, and when risk management is inadequate or ignored, variation orders will be high. Some studies have suggested that effective advance planning and evaluation could eliminate as much as 75% of variations (Harrison and Lock, 2017; Williams et al., 2019).

5. SYSTEMIC AND REGULATORY ISSUES

The construction manuals tend to be inadequately written at the organizational level. There are many fuzzy definitions of the performance-based constraints used. Weak enforcement of provisions is one of the other factors that contribute to ineffective VO avoidance (Arain and Pheng, 2005b; Sohail and Cavill, 2008; Pires, 2011). While performance-based design–build agreements can promote innovation, they can also help to take on too much specificity, making verification a challenge (Järvenpää et al., 2022). Methodologies such as the Last Planner System (LPS) may increase constructability, productivity, and scheduling reliability when properly supported (Shehab et al., 2023; Wangchuk et al., 2024).

This study used a multi-domain model where variation orders arise from interactions among stakeholder decisions, contractor characteristics, external pressures, management processes, and organizational rules, as shown in Figure 3. The integrative model provides a systematic way of seeing how individual factors combine to produce performance at the project level rather than just listing causes.

Materials and methods

This study investigated the causes and impacts of VOs in Nepal's Karnali Province Road construction works. It utilized a mixed quantitative and qualitative approach through questionnaires, case studies, interviews, field visits, and document reviews to gather data from contractors, consultants, and government clients.

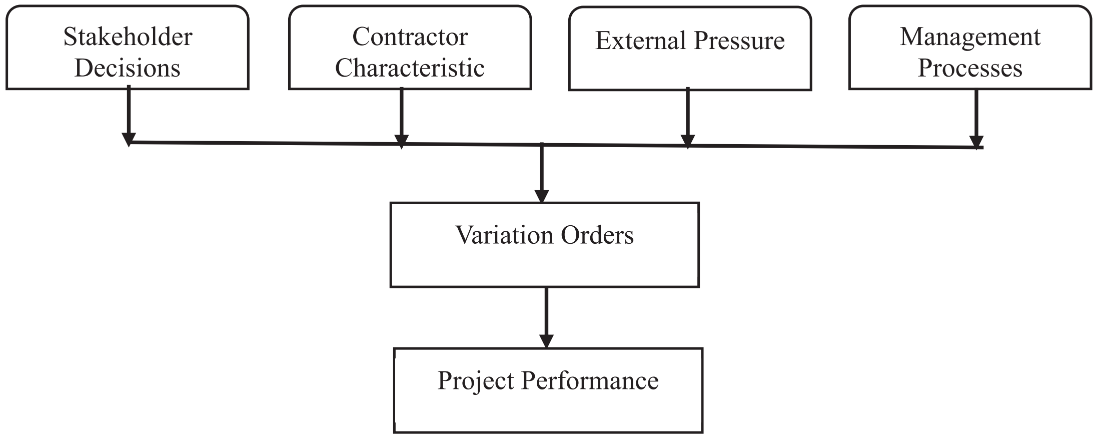


Figure 3. Proposed conceptual model of investigation

As shown in Figure 4, the research process proceeds from a problem statement and literature review to objectives, methodology design, sampling, data collection, data analysis, and data presentation. The research aimed to investigate the causes and impacts of VOs in Karnali Road projects, together with the extent of stakeholder agreement. A mixed-methods approach was employed: quantitative data from stakeholder questionnaires with scaled answers and qualitative data from interviews, site visits, and document analysis. Analysis focused on VO causes and effects as perceived by contractors, consultants, and public clients.

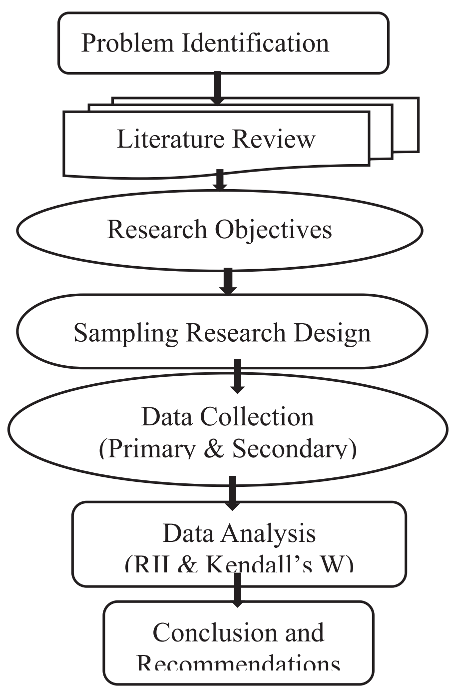
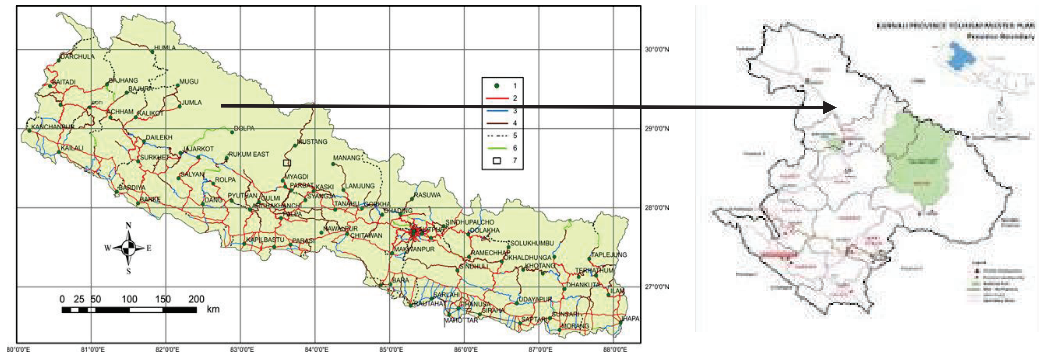


Figure 4. Research flowchart

Karnali Province, one of Nepal's seven provinces comprising 10 districts with Birendranagar as headquarters, served as the study setting. The MoPIUD implemented nine road projects in Karnali as contextual cases. A province map highlighting Karnali was used to orient readers to the setting, as shown in Figure 5.



(a) (b)

Figure 5. Research study area. (a, b) Map of Nepal and Karnali Province. Source: Nepal Road Network, Government of Nepal (GoN).

Table 1 provides a summary of the nine road and infrastructure projects being conducted in the Dailekh, Jumla, Surkhet, Rukum, Mugu, and Salyan districts of the MoPIUD, which include culverts, gabion walls, roadside improvements, blacktop works, airport road packages, and rural road works. The implementing agencies were the Road Offices and Infrastructure Development Offices (IDOs) and different contractors, as well as subcontractors.

Table 1. Study projects

S.N	Employee	Main project name	Construction firm
1	In the Dailekh district, Hume pipe culverts, gabion walls, roadside improvement, structures, and blacktop work are located along Mathillo Dungeshwor, Purakhet, and Lalikanda Package 3.	Road Office Jumla under MoPIUD	M/S Masding Devi/ Mission JV Baneshwor
2	Construction of Jumla AirportUrthu Khali Naurighat Bulbule Mugu–Package 1, Chainage 1+000 to 5+350.	IDO, Jumla under MoPIUD	M/S Baniya Nirman Sewa Pvt Ltd, Hetauda-1
3	Construction of Jumla Airport Urthu Khali Naurighat Bulbule Mugu–Package 3, Chainage 19+600 to 25+100	IDO, Jumla under MoPIUD	M/S Dhulikhel Kusheswor JV, Basundhara, Kathmandu
4	Ratna Rajmarg–Naya Gaun–Ghusra–Engineering Campus–Sano Surkhet Road, Surkhet Package 4.	Road Office, West Rukum under MoPIUD	M/S Mahalaxmi - Kirateshwor - KSK JV, Kathmandu
5	Improvement along Pipira–Deuti Bajai–Dholdhunga–Tharugaun–Amritdanda Road, Package 4.	Road Office, West Rukum under MoPIUD	M/S Mahalaxmi - Kirateshwor - KSK JV, Kathmandu

Table 1. continued

S.N	Employee	Main project name	Construction firm
6	Construction of Jima Sorukot Bhee Road, Soru, Mugu, Package 1.	IDO, Mugu under MoPIUD	M/S Thodung - RaraTenjin JV
7	Construction of Pina Balai Gamgadi Road, Mugu, Package 1.	IDO, Mugu under MoPIUD	M/S Thodung - RaraTenjin JV
8	Construction of Tharmare Badagaun Chaurjahari Road, Salyan, Package 1.	IDO, Salyan under MoPIUD	M/S Singh and Brothers Hamal JV
9	Roadway Improvement and Construction Work in Gongate Arunuda Dhadkhet Thala Jajarkot Road, Surkhet, Package 3.	IDO, Rukum under MoPIUD	M/S Lama/Rajendra/SNS JV, Surkhet

Note: MoPIUD, Ministry of Physical Infrastructure and Urban Development; IDO, Infrastructure Development Office.

POPULATION, FRAME, AND SAMPLING REPRESENTATIVENESS

The population of interest includes stakeholders involved in the MoPIUD road projects under implementation during the study period in Karnali Province: (i) contractors/subcontractors working on these projects, (ii) consultants engaged in design or supervision, and (iii) public clients/owners overseeing projects at federal, provincial, and local levels.

The sampling frame was developed using MoPIUD rosters, IDOs, and project documents from nine focal projects, i.e., creating a line list of personnel and their respective titles in the projects. Using a census approach, 21 contractors/subcontractors, 28 consultants, and 17 clients/owners (exposed to VO-related work) were identified as shown in Table 2. The coverage against the rosters for the violations and meeting records was checked to ensure that coverage and follow-up (e-mail, telephone, and site visits) were conducted to ensure that there was no nonresponse. It was assured that the respondent profiles were as close to matching the frame as possible, with only slight imbalances that were adjusted using post-stratification weighting, which did not involve any shifting of rankings. Inclusion required more than 3 years of experience in that sector and any involvement in a VO-affected project that was formed.

DATA COLLECTION

Primary data were collected using structured questionnaires with a 5-point Likert scale (1 = never to 5 = always) to capture perceived frequency/importance of VO causes and effects. Focused interviews and field visits were conducted to contextualize survey responses and clarify item interpretation. Secondary data comprised MoPIUD records and project documents, complemented by publicly available reports and academic literature, to describe the project context, verify VO incidence, and support triangulation, instrument development, quality control, and preprocessing. Questionnaire items were adapted from prior construction management studies that employed the Relative Importance Index (RII) for factor ranking, with alignment to Nepalese contract and practice contexts (Kometa et al., 1994; Sambasivan and Soon, 2007). Expert review and a pilot test refined wording and response scale clarity. Internal consistency (Cronbach's α) was assessed by construct, and pilot debriefs were used to confirm item comprehension. Responses were screened for missingness, straight-lining, and outliers. Minimal missing data were managed by listwise deletion at the item level; simple imputation was explored in sensitivity checks to ensure robustness.

Table 2. Population and sampling

S.N.	Project	Clients (project unit assigned)	Consultants		Total consultant	Contractors/ subcontractors
			Design	Supervision		
1	Project 1 (3 packages)	2 clients	1	3	4	3
2	Project 2 (1 package)	1	1	1	2	1
3	Project 3 (3 packages)	2 clients	1	3	4	3
4	Project 4 (4 packages)	3 clients	1	4	5	4
5	Project 5 (4 packages)	3 clients	1	4	5	4
6	Project 6 (1 package)	1	1	1	2	1
7	Project 7 (1 package)	1	1		1	1
8	Project 8 (1 package)	1	1		1	1
9	Project 9 (3 packages)	3 clients	1	3	4	3
Total		17	9	19	28	21

DATA ANALYSIS

- Relative Importance Index

The RII is a method that ranks causes and effects using ordinal Likert responses. It is widely used in construction research to compare differences in perceptions both across stakeholder groups and within groups (Kometa et al., 1994; Sambasivan and Soon, 2007). Logically, let A denote the highest scale weight (A = 5), N the number of respondents for that item, W the Likert weight (Oloo et al., 2014; Dhakal, 2024), and f the frequency count of responses for weight W. Thus, RII was computed as RII = $\sum (W \times f)/A \times N$, normalized. RII values range from 0 to 1, with higher values indicating greater perceived frequency or importance. The RII results were reported for the overall sample as well as by individual stakeholder groups, together with their respective item rankings. Where feasible, estimation uncertainty was quantified using 95% bootstrap confidence intervals (1,000 resamples).

The rationale and assumptions for RII are that ordinal Likert responses are treated approximately as an interval for purposes of averaging, that respondents interpret items consistently, and that item-level response counts are sufficient for reliable estimation. A recognized limitation of RII is sensitivity to group-specific scale use and potential masking of dispersion; to mitigate these concerns, we (i) report group-wise RII and ranks, (ii) complement mean-based indices with rank-based summaries, and (iii) conduct sensitivity checks using medians and post-stratified weights.

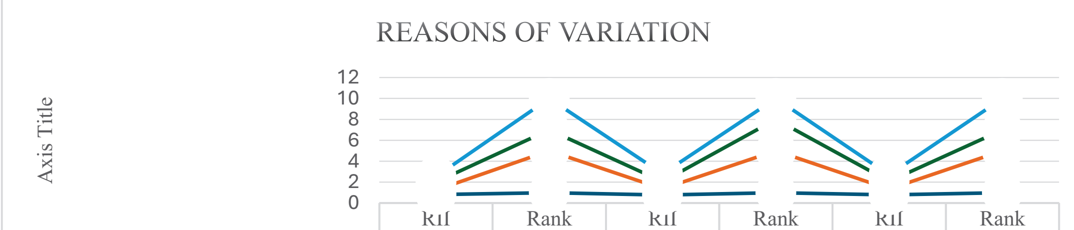
- Kendall's coefficient of concordance (W)

To assess the degree of agreement in rankings of VO factors among contractors, consultants, and clients, Kendall's coefficient of concordance (W) was computed. Let m be the number of rater groups (m = 3) and n the number of items (VO factors). For each item, the rank sums across groups were calculated, and the mean rank sum $\bar{R}$ was obtained; tie corrections were applied where required. The resulting W ranges from 0 (no agreement) to 1 (perfect agreement) and provides a single omnibus measure of concordance across the three stakeholder groups. The formula is given as $S = \Sigma(R_j - \bar{R})^2$ and $W = \frac{12S}{m^{2}(n^{3}-n)}$. Approximate significance tests for W were reported as df = (n−1) $\chi^2 = m(n-1)W$. Since a single concordance coefficient does not indicate which items contribute to the disagreement, W was examined and increased using pairwise Spearman's rank correlations between stakeholder groups and subgroup rank tables to establish where divergence occurred. Assumptions underlying this procedure are that all groups rank the same item set, that ranks are ordinal and independent across groups, and that ties are handled appropriately. To further ensure robustness, sensitivity analyses were performed by re-ranking items using median-based ordinal scores and alternative tie treatments; these checks produced orderings consistent with the RII-based results. Representativeness was addressed through post-stratification by stakeholder group and district to reflect frame proportions; this adjustment did not materially change qualitative conclusions or the identity of top-ranked factors.

DATA ANALYSIS AND RESULTS

The questionnaire consisted of employees of the Infrastructure Development Directorate (IDD)/IDO of the Ministry of Physical Infrastructure and Urban Development, Karnali Province, and contractors and consultants operating in the province. The causes of variation orders were assessed using a 5-point Likert scale (1 = never to 5 = always) and ranked according to their RII.

Figure 6 shows the ranked reasons for VOs from the perspective of owners and clients. The figure shows that incomplete drawings at the bidding stage, too little pre-construction planning, and unclear project briefs are consistently ranked as the most significant drivers. This indicates that deficiencies in project preparation on the part of the clients, in terms of providing the needed information, have direct



	Client		Consultant		Contractor	
	RII	Rank	RII	Rank	RII	Rank
Impediment in prompt decision making process	0.529	3	0.74	2	0.609	3
Replacement of materials or procedures	0.765	2	0.693	3	0.745	2
The long waiting time to get approval drawings	0.435	4	0.58	4	0.545	4
"Additions, Omissions and Alterations" of the Employer's Requirements	0.812	1	0.78	1	0.791	1

Figure 6. Ordering reasons for variation related to owners and clients

consequences on scope changes and alterations in review and design. We are ultimately interpreting the rankings to mean that greater success in identifying improvement significance and priority will substantially reduce VO prevalence and project costs and schedule overruns. If we can improve project briefs, make sure our designs are complete and ready for tendering, and maximize early coordination, we will observe significant reductions in VOs and their associated costs.

Table 3 shows agreement on two major sources of variation orders: design errors/omissions and inexperience of the design team. Contractors and clients prioritized change orders due to consultant-driven design changes, consultants pointed to conflicts in contract documents, and service contractors provided unique insights indicating that utility standards were compromised. Each stakeholder performs a specific function in the project.

Table 3. Variation order causes associated with consultants

S.N	Causes of variation orders	Client		Consultant		Contractor	
		RII	Rank	RII	Rank	RII	Rank
1	Change in design and drawings by consultant	0.800	1	0.767	3	0.818	2
2	Errors and omissions in design documents	0.788	2	0.933	1	0.864	1
3	Conflicts between contract documents	0.682	5	0.633	6	0.636	5
4	Inadequate design team experiences	0.753	4	0.740	4	0.700	4
5	Lack of knowledge among consultancies regarding availability	0.788	2	0.813	2	0.809	3
6	Insufficient time for the preparation of contracts, materials, and equipment.	0.647	7	0.593	7	0.573	7
7	Inadequate documents in working drawing details	0.682	5	0.713	5	0.627	6
8	Failure to observe all other parties' requirements (water, electricity, etc.)	0.482	8	0.567	8	0.518	8

In Table 4, contractor-related factors that change the construction process were rated the highest for both consultants and contractors, which reveals shared concern about inefficiencies within the process. Clients emphasized contractor profit and workmanship and connected them directly to quality control and cost overruns.

In Table 5, we observed that contractors and clients identified beneficiary initiatives as the primary external cause of variation, while consultants highlighted land and resettlement aspects, indicative of their greater involvement in pre-construction planning. All groups considered design errors and omissions, as well as lack of design team experience, to be important drivers of variation, reinforcing the importance of the quality of design in the project. Contractors and clients considered changes to design and drawings initiated by the consultant to be the most disruptive to construction, while consultants favored the incoherence of instructions in the contract documents, which was consistent with their contractual obligations. Stakeholders generally agreed on design-related causes, but their views varied by role, indicating the need for better coordination in design, documentation, and decision-making. Kendall's W showed only moderate agreement, which reflects the disjointed thinking of the stakeholders.

Table 4. Variation order causes connected to contractors

S.N	Causes of variation orders	Client		Consultant		Contractor	
		RII	Rank	RII	Rank	RII	Rank
1	Improper control over site resource allocation	0.671	4	0.660	4	0.518	4
2	Subcontractor and petty allocation of work	0.612	5	0.660	4	0.500	5
3	Defective workmanship	0.729	2	0.733	3	0.545	2
4	Modifications to the construction process	0.729	2	0.840	1	0.736	1
5	Contractor's desired profitability	0.800	1	0.767	2	0.527	3

Table 5. Variation order causes connected to the external environment

S.N	Causes of variation orders	Client		Consultant		Contractor	
		RII	Rank	RII	Rank	RII	Rank
1	Weather conditions	0.435	4	0.533	5	0.482	6
2	Acts of God (floods,landslides)	0.494	3	0.607	2	0.564	2
3	Land/resettlement problems and other unseen social issues	0.541	2	0.620	1	0.555	3
4	The time gap between the design and the actual start of works after bidding and procurement	0.424	5	0.560	4	0.555	3
5	Interventions of beneficiaries	0.553	1	0.607	2	0.591	1
6	Interventions of others in the decision-making process	0.424	5	0.513	6	0.527	5

CASE STUDIES

This research used case studies to identify the primary causes and impacts of variation orders on selected road projects under the MoPIUD, Karnali Province. Information was obtained from MoPIUD offices and double-checked with contractors' and consultants' reports.

As shown, nine projects across 17 packages were studied, with site variations occurring in 11 locations listed in Table 6, presenting 11 construction projects detailing their owners, contractors, causes of variations, and types of variations.

CAUSAL EXPLANATION OF VARIATION ORDERS

Apart from descriptive reporting, the analysis indicates that variations were most frequently caused by (i) unforeseen site conditions such as landslides and high water tables, (ii) incomplete drawings and design revisions, (iii) scope variations due to land acquisition issues, and (iv) resource movement between overlapping projects. All these causative factors add up to systemic issues in the planning and design stages

Table 6. Variation order causes in research projects

S.N	Project name	Causes of variations	Variation type
1	In Dailekh, Hume pipe culverts, gabion walls, roadside works, and blacktop structures are located in Mathillo Dungeshwor, Purakhet, and Lalikanda	Gabion and masonry work increased, whereas blacktop, Hume culverts, Reinforcement Cement Concrete (RCC) causeways, and traffic safety work decreased.	Addition and omission
2	Jumla Airport to Bulbule Mugu, Package 1, Chainage 1+000–5+350	Road widening, more excavation, and gabions due to landslide risk, plus other item changes.	Addition and omission
3	Jumla Airport to Bulbule Mugu, Package 3, Chainage 19+600–25+100	Excavation of roads and drains in all soils and rocks, manual or mechanical, including stumps and landslide-related items, per specifications and engineer's instructions.	Addition and omission
4	Ratna Rajmarg–Naya Gaun–Ghusra–Engineering Campus–Sano Surkhet Road, Surkhet	Walkway not built due to land acquisition issues; 380-m firm pavement added for high water table, with other item changes.	Alteration
5	Improvement along Pipira–Deuti Bajai–Dholdhunga–Tharugaun–Amritdanda Road	Of the 4-km blacktop planned, 3 km was completed; 1 km had already been completed by IDD Surkhet. For road facilities, only 1,500 m remained, so the balance was used for blacktop.	Alteration
6	Construction of Jima Sorukot Bhee Road, Soru, Mugu	Addition and omission in excavation item.	Alteration
7	Construction of Pina Balai Gamgadi Road, Mugu	Addition and omission in excavation item.	Alteration
8	Construction of Tharmare Badagaun Chaurjahari Road, Salyan	The design required a narrower road and extra work, including a passing lane bend, pavement base and subbase expansion, and RCC works.	Alteration
9	Roadway Improvement and Construction Work in Gongate Arunuda Dhadkhet Thala Jajarkot Road, Surkhet	"Embankment formation" quantity decreased, and "hard rock excavation" quantity increased.	Addition and subtraction
10	Upgrading of Pradesh Rajdhani Birendranagar Planning Area Urban Road (Package 3), Surkhet	"Formwork, reinforcement, plumb concrete, premix carpeting" quantity increased, and "earthwork, site clearance items" quantity decreased.	Addition and subtraction
11	Upgrading of Pradesh Rajdhani Birendranagar Planning Area Urban Road (Package 2), Surkhet	Quantities of formwork, reinforcement, plumb concrete, and premix carpeting increased, while earthwork and site clearance decreased.	Addition and subtraction

Note: IDD, Infrastructure Development Directorate.

rather than to occasional project-specific anomalies. For instance, additional excavation and gabion works within Jumla projects were undertaken because of unexpected landslide risks, whereas the exclusion of walkway construction within Surkhet was directly linked to unresolved land acquisition disputes.

TRIANGULATION WITH SURVEY FINDINGS

The triangulation gap exists by connecting case study outcomes and survey evidence. The survey results given in Table 7 consistently ranked "preparation of drawings at the bidding stage" and "ensuring adequate pre-construction planning" as the first and second remedies, respectively. This is supported by the case studies, which detailed that inadequate designs and poor pre-site investigations were prevalent causes of VOs (e.g., Projects 4 and 5). Similarly, the survey ranked "resolving land acquisition issues prior to construction" as a concern, which aligns with the Surkhet case in which land disputes resulted in an altered project scope.

Again, cross-validation between methods increases our confidence in our results, and as shown in Table 7, there is consistency across both qualitative case data and quantitative survey perceptions that points to similar causal agents.

IMPACT OF VARIATION ORDERS

Variation orders typically result in overrunning time delays, which push the project completion date back, and budget overruns, which increase the overall project cost.

The lines of evidence shown in Tables 8 and 9 indicate that variation orders typically lead to cost increases (up to 15%) and schedule extensions (up to 86%) on projects. Both the case study findings and survey opinions indicate "schedule delay" and "increase in cost" as the two largest impacts, which further strengthen our findings. Therefore, to remedy the above problems, appropriate management of VOs in Karnali Province should rely on addressing both technical and institutional gaps. Greater project pre-construction planning, including full designs, comprehensive site investigations, and leveraging technology [geographic information system (GIS) and light detection and ranging (LiDAR)], will assist in lessening design VOs. Institutional reform will be focused on empowering the provincial contemporary design offices, facilitating the approval process, and introducing transparent digital systems to inhibit political influence and development delays. Introducing standard VO clauses with fair risk-sharing, contractor incentives for effective VO use, and staff training on accountability will improve transparency and enhance VO management performance. At a policy level, an approach to prohibit provincial VO guidance consistent with national acts and a centralized VO database will assist evidence-based VOs. All these institutional and technical opportunities will assist in lessening unnecessary variations, monitoring cost and time overruns, and improving resilience around projects.

IMPACT OF VARIATION ORDERS ON ROAD PROJECTS IN KARNALI PROVINCE

A case study of MoPIUD road projects in Karnali Province indicated that variation orders led to increases in both costs (Table 8) and duration (Table 9). Stakeholders recommended solutions for these increases, including pre-tender drawings, enhanced pre-construction planning processes, designing with similar budget constraints, improved teamwork through the design and construction team, and ensuring communication effectiveness, along with some group-specific issues.

Schedule overruns occurred between 6.7% and 86%, as illustrated in Table 9. Notably, there were large delays with the remote, geologically unstable projects (for example, Pina Balai Gamgadi Jumla and Airport to Bulbule Mugu). There were smaller project delays in projects that were less remote or complex. These conclusions illustrate that terrain, site conditions, and capacity gaps within institutions result in project delays. The rest of the data suggest that project delays are due to complications and that value for money

Table 7. Opinions of respondents on reducing variation orders

S.N	Causes of variation orders	Client		Consultant		Contractor	
		RII	Rank	RII	Rank	RII	Rank
1	Complete the drawings during the bidding process.	0.929	1	0.933	1	0.936	1
2	Conduct thorough site inspections, including detailed soil research, and take it into consideration while preparing a tender.	0.835	3	0.833	3	0.845	2
3	Ensure sufficient planning by all involved parties prior to commencing work on site.	0.847	2	0.847	2	0.845	2
4	The consultant should produce a concluding design and contract documents.	0.812	7	0.820	8	0.827	5
5	During the construction phase, the consultant should closely coordinate.	0.824	4	0.820	8	0.818	9
6	Supervise the job with a committed and experienced engineer.	0.824	4	0.827	5	0.827	5
7	Place experienced and knowledgeable executives in the engineering and design department.	0.824	4	0.827	5	0.827	5
8	Consultants should ensure that the design/specifications fall within the approved budget.	0.800	10	0.807	10	0.809	10
9	Clients must provide a precise project brief.	0.741	13	0.733	13	0.755	11
10	All parties must anticipate unforeseen circumstances.	0.753	11	0.753	12	0.755	11
11	Enhance communication between all parties.	0.753	11	0.760	11	0.755	11
12	Obtain accurate information and research regarding procurement, materials, and equipment.	0.741	13	0.733	13	0.727	14
13	Avoid making any alterations in the specifications once the tender is awarded.	0.812	7	0.833	3	0.836	4
14	Resolve land acquisition and social issues prior to commencing construction.	0.812	7	0.827	5	0.827	5

Table 8. The effect of variation orders on investigated road projects in the Province of Karnali

S.N	Project name	Original contract amount (Rs)	Revised contract amount (Rs)	Variation amount (Rs)	VO%
1	In Dailekh, Hume pipe culverts, gabion walls, roadside works, and blacktop structures are located in Mathillo Dungeshwor, Purakhet, and Lalikanda	145,732,574.4	146,117,175.5	384,601.1	0.26
2	Jumla Airport to Bulbule Mugu, Package 1, Chainage 1+000–5+350	47,765,480.15	54,379,903.11	6,614,422.96	13.85
3	Jumla Airport to Bulbule Mugu, Package 3, Chainage 19+600–25+100	54,391,832.87	61,005,270.87	6,613,438	12.16
4	Ratna Rajmarg–Naya Gaun–Ghusra–Engineering Campus–Sano Surkhet Road, Surkhet	217,480,517.2	217,020,371.6	-460,145.6	-0.21
5	Improvement along Pipira–Deuti Bajai–Dholdhunga–Tharugaun–Amritdanda Road	179,121,116.5	179,304,011.2	182,894.65	0.10
6	Construction of Jima Sorukot Bhee Road, Soru, Mugu	25,728,256.92	29,605,450.94	3,877,194.02	15.07
7	Construction of Pina Balai Gamgadi Road.	28,987,644.05	28,906,384.05	-81,260	-0.28%
8	Construction of Tharmare Badagaun Chaurjahari Road, Salyan	61,226,066.5	66,959,924.5	5,733,858	9.37
9	Roadway Improvement and Construction Work in Gongate Arunuda Dhadkhet Thala Jajarkot Road, Surkhet	225,639,655.8	254,592,167.3	28,952,511.49	12.83
10	Upgrading of Pradesh Rajdhani Birendranagar Planning Area Urban Road (Package 3), Surkhet	86,865,395.8	98,752,644.52	11,887,248.72	13.68
11	Upgrading of Pradesh Rajdhani Birendranagar Planning Area Urban Road (Package 2), Surkhet	63,630,188.65	66,757,074.73	3,126,886.08	4.91

Source: Karnali Province, MOPIUD.

Note: VO, variation order.

Table 9. Completion schedule delay in selected projects

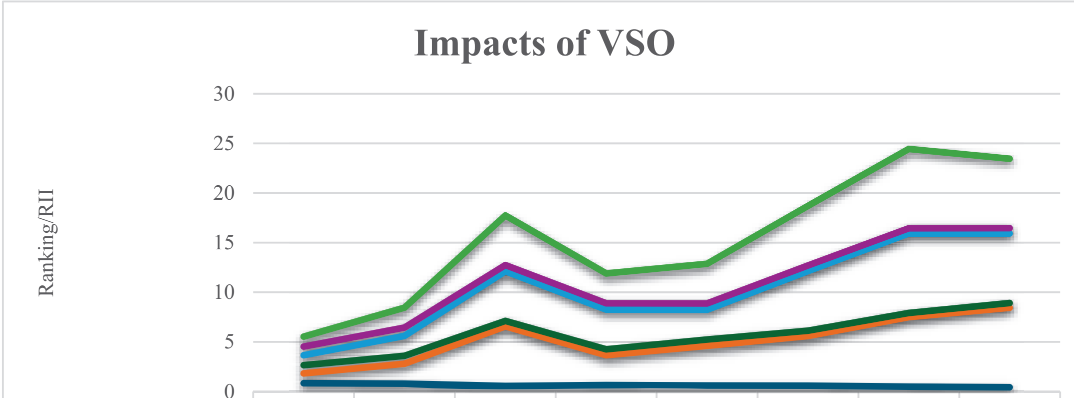
S.N	Project name	Contract project duration (months)	Actual project duration (months)	Increase in duration (%)
1	In Dailekh, Hume pipe culverts, gabion walls, roadside works, and blacktop structures are located in Mathillo Dungeshwor, Purakhet, and Lalikanda	49.3	55.9	13.38
2	Jumla Airport to Bulbule Mugu, Package 1, Chainage 1+000–5+350	13.9	20.6	48.80
3	Jumla Airport to Bulbule Mugu, Package 3, Chainage 19+600–25+100	12.6	18.3	45.62
4	Ratna Rajmarg–Naya Gaun–Ghusra–Engineering Campus–Sano Surkhet Road, Surkhet	48.1	53.8	11.92
5	Improvement along Pipira–Deuti Bajai–Dholdhunga–Tharugaun–Amritdanda Road.	42.6	45.4	6.73
6	Construction of Jima Sorukot Bhee Road, Soru, Mugu	1.8	2.8	55.56
7	Construction of Pina Balai Gamgadi Road, Mugu	6.5	12.0	86.08
8	Construction of Tharmare Badagaun Chaurjahari Road, Salyan	15.2	21.2	39.69
9	Roadway Improvement and Construction Work in Gongate Arunuda Dhadkhet Thala Jajarkot Road, Surkhet	55.6	68.4	23.08
10	Upgrading of Pradesh Rajdhani Birendranagar Planning Area Urban Road (Package 3), Surkhet	18.5	22.9	24.01
11	Upgrading of Pradesh Rajdhani Birendranagar Planning Area Urban Road (Package 2), Surkhet	17.8	22.9	28.65

Source: Karnali Province, MOPIUD.

(VfM) depends on planned controls, full engagement by all stakeholders, and realistic contingencies, leading to delays that are process-based rather than purely number-based when considering the extent of technical issues involved or governance.

IMPACTS OF VARIATION ORDERS

Figure 7 consolidates stakeholder perceptions (clients, consultants, and contractors) on the impact of VOs. In all stakeholder categories, participants ranked cost increase and time delay as two of the most significant effects, including resources and quality as lower priorities. The differences in contractor, client, and consultant stakeholder rankings likewise contribute to a richer understanding of priorities for the various stakeholders. For instance, contractors ranked constructability and labor management higher than other stakeholder groups. Conversely, consultants tended to rank compliance and coordination lower. Comparing rankings of different impacts shows that managing VOs means managing multiple stakeholders. In addition, it involves clearly defined risk-sharing mechanisms, transparency in communication, and a well-considered balancing of cost, time, and quality.



	Completion schedule delay	Increase in project cost	Disputes among professionals	Progress is affected	Increase in overhead expenses	Procurement delay	Quality degradation	Restoring Company's Image After Setback
Contractor Rank	1	2	5	3	4	6	8	7
Contractor RII	0.873	0.845	0.618	0.636	0.627	0.573	0.527	0.536
Consultant Rank	1	2	5	4	3	6	8	7
Consultant RII	0.827	0.807	0.56	0.6	0.633	0.54	0.427	0.487
Client Rank	1	2	6	3	4	5	7	8
Client RII	0.824	0.788	0.553	0.647	0.6	0.576	0.482	0.424

Figure 7. Impact and ranking of variation orders according to the opinions of clients, consultants, and contractors

Agreement test: Kendall's coefficient of concordance assessed group-wise and overall rankings.

- **H0:** No agreement among respondent groups on the causes of variation orders.
- **H1:** Agreement exists among respondent groups.

Kendall's W for the owners/clients, consultants, contractors, and external environment factors is reported in Table 10 and measures the extent of agreement in each respondent group. The strong agreement (W = 791–0.978) across groups on the ranking of factors associated with variation orders indicates areas of considerable agreement among stakeholder groups. Consultants had the strongest degree of consensus compared to owners and contractors. The findings displayed here illustrate where stakeholders largely hold the same perceptions on what identified factors are the most significant to variation orders, and likewise, there are minor distinctions in the item factors based on respondents' corresponding roles. The move toward agreement quantification in the reporting of the results takes us a step further than just description, and the results clearly illustrate that even though agreement has been established, strategies to mitigate variation orders can be formed at a broader understanding of stakeholder priority while still addressing stakeholders' concerns.

Table 10. Group-wise rank using Kendall's coefficient test

Parameters	Owner/client-related factors	Consultant-related factors	Contractor-related factors	Factors related to the external environment
Respondent group (m)	3	3	3	3
Items ranked (n)	4	8	5	6
Kendall's coefficient of concordance (W)	0.911	0.978	0.791	0.800
Degree of freedom (n – 1)	3	7	4	5
Test statistics (X^2)	8.200	20.528	9.493	12.000
Tabulated value	7.815	14.067	9.488	11.070

AGREEMENT TEST ON VARIATION ORDERS

Kendall's coefficient of concordance was used to check agreement among groups of respondents with respect to both the impacts and causes of variation orders. All groups of respondents rated the completion of drawings at the tender stage as the most important impact, followed by sufficient pre-site planning, with the intention to reduce budget-aligned design/specifications. They also rated improvement in communication. Agreement was found to be lost for some of the other impacts. The same test was also performed with respect to the causes of variation orders and again showed both agreement and divergence among the groups. The null and alternative hypotheses being tested were as follows:

- H0: No agreement between groups.
- H1: Agreement does exist between groups.

From Table 11, we can observe that Kendall's W (0.968) for the ranked impacts of variation orders shows a very strong agreement among clients, consultants, and contractors. This agreeableness suggests that all participants perceive the high-impact consequences of VOs to be the same elements, namely, cost increase, schedule delays, and resource issues. The implications of this simple descriptive reporting impact how mitigation strategies should target high-impact consequences and give us a mutual basis for coordinated strategic action across stakeholders.

Table 11. Impact of variation orders

Parameters	Impacts of variation orders
Respondent group (m)	3
Items ranked (n)	8
Kendall's coefficient of concordance (W)	0.968
Degree of freedom (n – 1)	7
Test statistics (X^2)	20.333
Tabulated value	14.067

Rank-order correlation on measures to reduce variation orders:

- H0: There is no agreement on measures to minimize variation orders among groups.
- H1: Agreement on the measures exists among groups.

Kendall's W for clients, consultants, and contractors is shown in Table 12 and is 0.924, indicating that these groups of respondents agreed strongly in the ranking of measures to avoid variation orders. The value of the test statistic at 36.045 is greater than the tabulated value at 22.362, confirming sufficient statistical evidence that the level of concordance was significant. Concordance implied that all three stakeholder groups were able to agree on priority mitigations and, therefore, provide a shared understanding for coordinated actions. Furthermore, supplemental to a descriptive report of the data, these results signal that mitigation can be targeted and undertaken based on these topline high-priority initiatives that everyone has collectively recognized, which should improve the efficiency and value talked about in VO management.

Table 12. Group-wise rank using Kendall's coefficient test

Parameters	Variation order mitigation measures
Respondent group (m)	3
Items ranked (n)	14
Kendall's coefficient of concordance (W)	0.924
Degree of freedom (n – 1)	13
Test statistics (X^2)	36.045
Tabulated value	22.362

Discussion

Rather than repeating descriptive rankings, this discussion explains why VOs endure in Karnali Province and what reforms they demand. We used a context, capability, coordination lens: (1) rugged topography and remoteness drive uncertainty, (2) institutional and technical capacity shape design and decision quality, and (3) multi-actor coordination determines responsiveness to change. This frame links local evidence to global scholarship and to practicable governance and procurement reforms.

- **Scope volatility**

Scope volatility in Karnali is not a generic "top cause" but a foreseeable consequence of mountainous terrain, geologic instability, and constrained access: frequent landslides, shifting ground, and weak logistics make *ex ante* information imperfect, enlarging contingencies and prompting additions, omissions, and design changes. This extends global findings that scope change fuels VOs (Halwatura and Ranasinghe, 2013; Alzubi et al., 2023) by showing that severe topography magnifies scope risk and that staged investigation and flexible designprocurement bundles (e.g., staged site investigations, GIS/LiDAR, and flexible specifications) are preferable to attempts to eliminate scope change entirely (Corominas et al., 2014; Gnyawali et al., 2020; Leijten, 2017).

- **Consultant capacity**

Consultant errors, omissions, and delayed design revisions reflect structural capacity shortfalls—compressed preparation periods and under-resourced provincial design offices—that produce incomplete designs, as documented in comparable settings (Enshassi et al., 2010; Carrillo et al., 2013; Nguyen et al., 2023). In Karnali, these capacity gaps compound terrain-driven uncertainty, increasing VO incidence and pointing to reforms such as independent design review for complex corridors, mandated geotechnical baselines, and procurement that rewards robust design.

- **Coordination and governance**

Divergent stakeholder priorities, contractors and clients stressing material substitution and constructability, and consultants highlighting decision bottlenecks signal coordination failures under Nepal's decentralized governance (Giri et al., 2025). Local bodies often lack technical and digital capacity for timely approvals, while line agencies face incentive misalignment and political interference (Gnyawali et al., 2020; Noruwa et al., 2022). Fragmented accountability yields only moderate consensus (captured by Kendall's W) (Sudusinghe and Seuring, 2025). Remedies include time-bound approval workflows, transparent digital clearance trails, and escalation protocols codified in the public procurement act (PPA)/public procurement regulation (PPR) to convert *ad hoc* engagement into enforceable decision rights.

- **Contractor-originated variations**

Contractor-originated VOs—method changes, workmanship defects, and profit-driven adjustments—arise from market imbalances. Governance should therefore shape the market: strengthen prequalification (financial capacity and staff retention), calibrate performance securities, adopt incentive-compatible payments (e.g., milestone payments tied to quality), and selectively use design–build or early contractor involvement on geotechnically uncertain corridors to share risk and reduce late variations (Oyewobi et al., 2016; Uzzi, 2020).

- **Resettlement and social pressure**

External pressures, resettlement disputes, and beneficiary interventions are central in Karnali. Complex land tenure and sociopolitical mobilization render a right of way fluid (Mahat, 2019). Front-loading social license through negotiated easements, realistic compensation, and community monitoring reduces later changes; institutionalizing these steps in project readiness gates aligns practice with international best practice and curbs construction-phase VOs (Notess et al., 2021; Panday et al., 2021; Abougamil et al., 2024).

- **Planning and design quality (policy implication)**

Strengthening planning and design is essential to curb VOs in transport projects. For mountainous corridors, agencies should adopt staged investigations supported by geotechnical baseline reports (Cascetta and Cartenì, 2014; Paudyal et al., 2023; Said et al., 2024). An independent designreview panel for Category A roads, adequate resourcing of provincial design offices, and wider use of quality and cost based selection (QCBS), with attention to long-term maintenance and design completeness, will raise standards and lower variation costs (Han et al., 2019; Roy et al., 2024).

- **Decision rights and approval governance (policy implication)**

Governance must clarify decision rights and impose time-bound processes. The PPA/PPR should specify VO approval timelines and mandate electronic VO modules with audit trails to limit political interference and boost transparency (H. K. Doloi, 2011; Sewell et al., 2019b). Defining provincial and local decision authority and maintaining a single, accessible decision log will streamline approvals and remove duplication.

- **Procurement and contractor market development (policy implications)**

Procurement reform should cultivate a stronger contractor market: stringent prequalification (financial standing, equipment, and in-house QA/QC), limits on cascading subcontracting, and performance-based incentives and penalties. For highuncertainty projects, risk-sharing contracts should be adopted (target price with pain/gain or new engineering contract (NEC)-style options), and VO clauses on admissibility and valuation should be standardized to reduce disputes (Ahmed, 2020; Akram et al., 2022; Pillai et al., 2002).

- **Stakeholder engagement (policy implication)**

Stakeholder engagement must be tied to project milestones, forums at design freeze, right-of-way readiness, and utility relocation before a notice to proceed, and resettlement governance strengthened with community verification and grievance redress timelines (Iskandarani, 2023). These measures align participation with readiness and reduce executionphase delays and conflicts.

- **Conceptual contribution**

This study advances VO literature by showing how extreme topography and decentralized governance jointly amplify VO likelihood and duration: terrain creates uncertainty, capacity shortfalls translate uncertainty into design defects, and weak coordination escalates defects into costly delays and variations. Addressing VOs in Karnali, therefore, requires better technical information and clarified decision rights (Arain and Pheng, 2005a; Narayanan et al., 2020; Amzafi et al., 2024; Shugran and Ghazali, 2024; Cadaval-Sampedro et al., 2025; Castañeda et al., 2025).

In sum, while global trends mirror the drivers of VOs in Karnali, Nepal's distinctive geography, institutional capacity constraints, and governance arrangements render VOs more frequent and consequential. Integrating technical improvements with system-level governance reforms is therefore essential to minimize cost overruns and delays in provincial infrastructure development.

Ethics statement

The research described in the article adheres to ethical standards and guidelines. Any experiments involving human subjects or animals have been conducted with the necessary ethical approvals and informed consent.

Author contributions

The authors confirm significant contributions to the conception, design, data collection, analysis, and interpretation of this article.

Originality and plagiarism

This work is original, unpublished elsewhere, with all external sources properly cited. No plagiarism or unethical use of intellectual property is present.

Compliance with journal guidelines

The submission follows all editorial policies, and required permissions have been obtained.

Authorship order

The order of authorship reflects the relative contributions of each author to the research. The lead author takes responsibility for the integrity and accuracy of the work.

Data availability statement

The authors will make data and supplementary materials available upon request, with any data restrictions outlined in the article.

Conclusions and recommendations

This study sought to assess the reasons for and implications of variation orders in road construction projects in Karnali Province, Nepal, through a review of the literature, a survey, and a case study. There are some lessons that can be replicated from the world and some that are province-specific.

Overall findings substantiate that variation orders usually arise from scope changes, design errors, and incoordination between the parties. These factors have been ongoing in foreign literature and were prominent in this study as well.

Site-specific lessons show how Karnali's mountains, lack of connectivity, and lack of professional capacity create more variation orders. Unstable geology and frequent landslides require constant scope change, and decentralized governance means there are delays and sometimes roadblocks to decisions. Likewise, the limited small contractors influenced by local politics and limited institutional capacity within provincial offices increased issues around quality and resource management.

Karnali variation orders were observed to significantly increase costs and time overruns, which brings attention to the need for implementing targeted interventions.

Recommendations should therefore be based on an explicit priority framework, as follows:

- Improve design quality: Invest in provincial design staff training and resources to minimize drawing mistakes.
- Improve project governance: Simplify approvals and improve organizational decisions to reduce unnecessary project delays.
- Improve contractor performance: Improve contractor capacity, qualification, and monitoring to limit profit-motivated alterations.
- Minimize external risk: Conduct early community engagement, consultations, and resettlement planning to decrease additional risks of conflict.
- Improve integrated planning: Promote timely integrated interactions between clients, consultants, and contractors and develop accurate estimates that do not exceed the prescribed project scope.
- National collaboration: Develop national guidelines and conduct collaborative capacity-building research and development studies that involve government, industry, and academics.

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